Loading and structural performance of tandem bicycle frames

MARK TAYLOR/STUFF

Digby Symons – SESNZ Conference- UC – 26th November 2020

Loading and structural performance of tandem bicycle frames

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[1] Mechanical Engineering, University of Canterbury, NZ

Acknowledgements:

Peter Alexander, Zenyth Projects Ltd

Damian Wiseman, Paralympics New Zealand

Motivation: 8 out of 50 Paralympic cycling medals contested on tandems

Paralympic cycling classes:

- C 1-5: Cyclists with an impairment capable of using a standard bicycle
- T 1-2: Cyclists with balance impairment use a tricycle
- H 1-4: Cyclists with leg impairment use a handcycle
- **B: Blind and visually impaired cyclists use a Tandem bicycle with a sighted pilot on the front - both athletes are awarded medals**

Neil Fachie and Matthew Rotherham (GBR)

Motivation: Tandem frame design is a challenge

Conflicting design needs:
- Low mass, good aerodynamics
- High stiffness and strength

Structurally worse than solo bicycle:
- Much higher loading
- Longer wheelbase

Medals for para-sport events in the Commonwealth Games, such as para-cycling tandem sprint, count towards national medal tallies. Tim Ireland/PA

Motivation: Not a new problem [1]

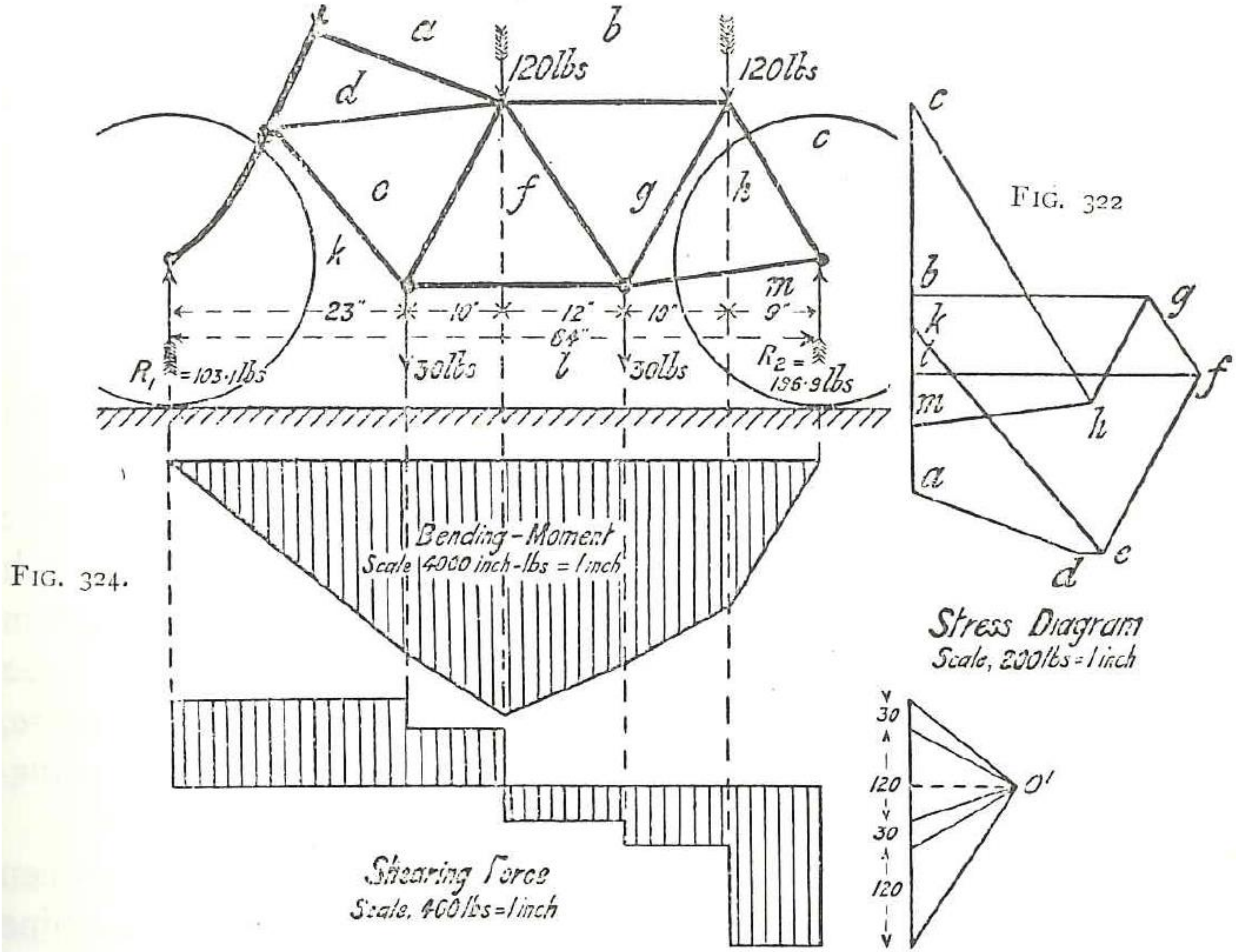

FIG. 324.

FIG. 322

[1] Sharp, A. (1896) Bicycles and Tricycles: An Elementary Treatise on Their Design and Construction. Longmans, Green, UK.

Motivation: Despite UCI rules, no single design universally adopted to date

Double diamond

Direct lateral

Marathon

Open frame

Method: Load case – starting effort

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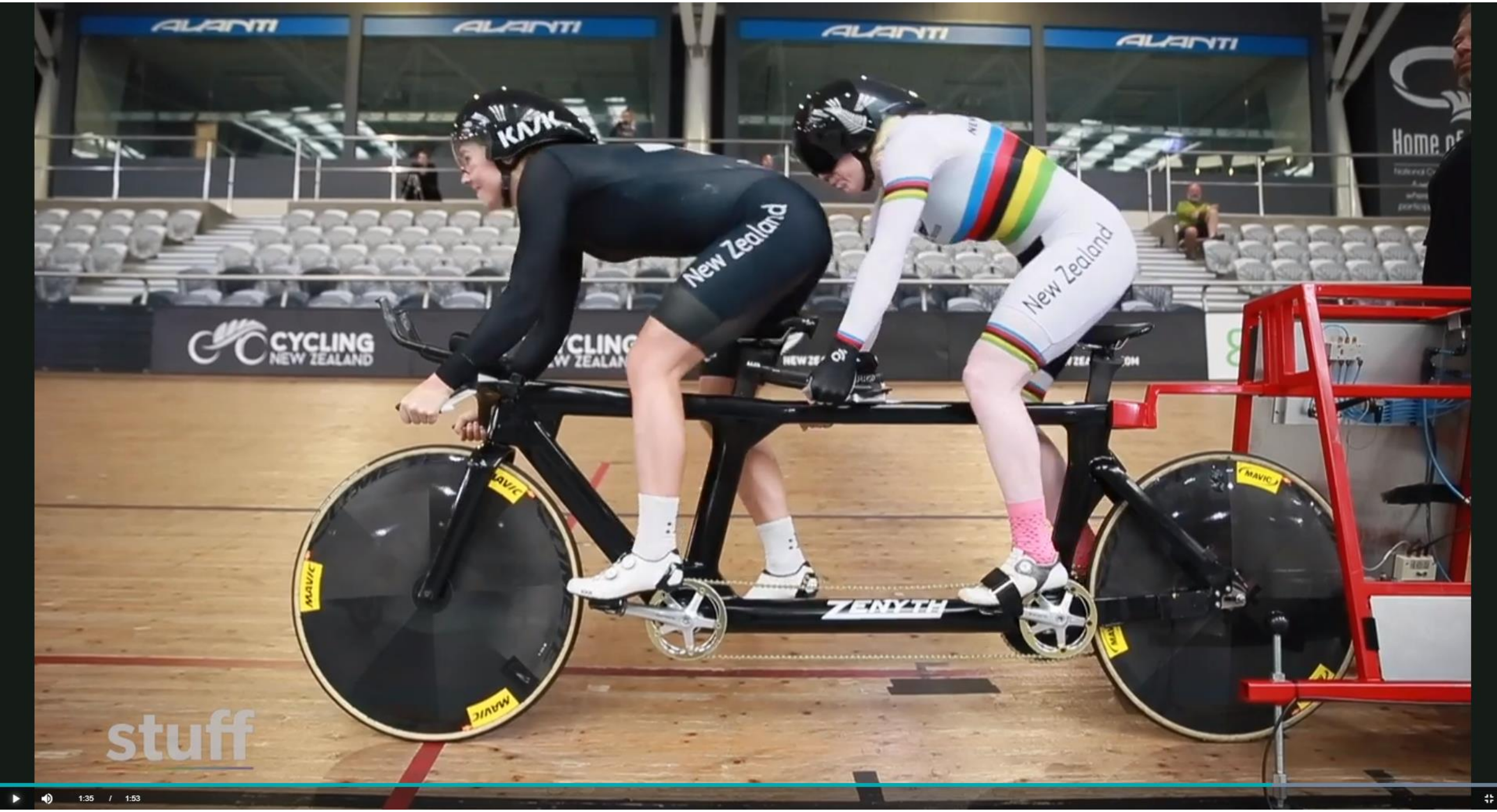
Method: Load case – starting effort



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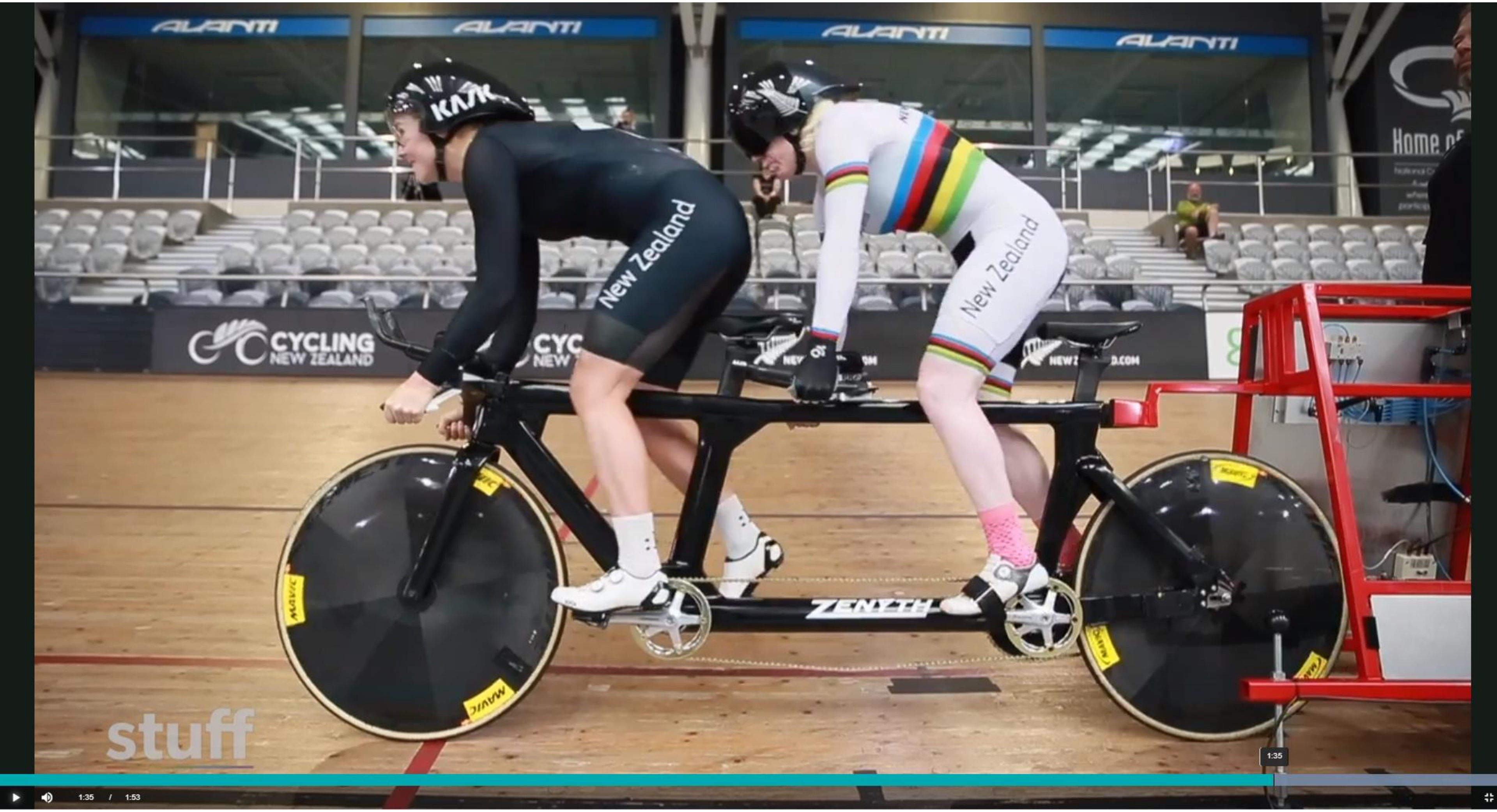

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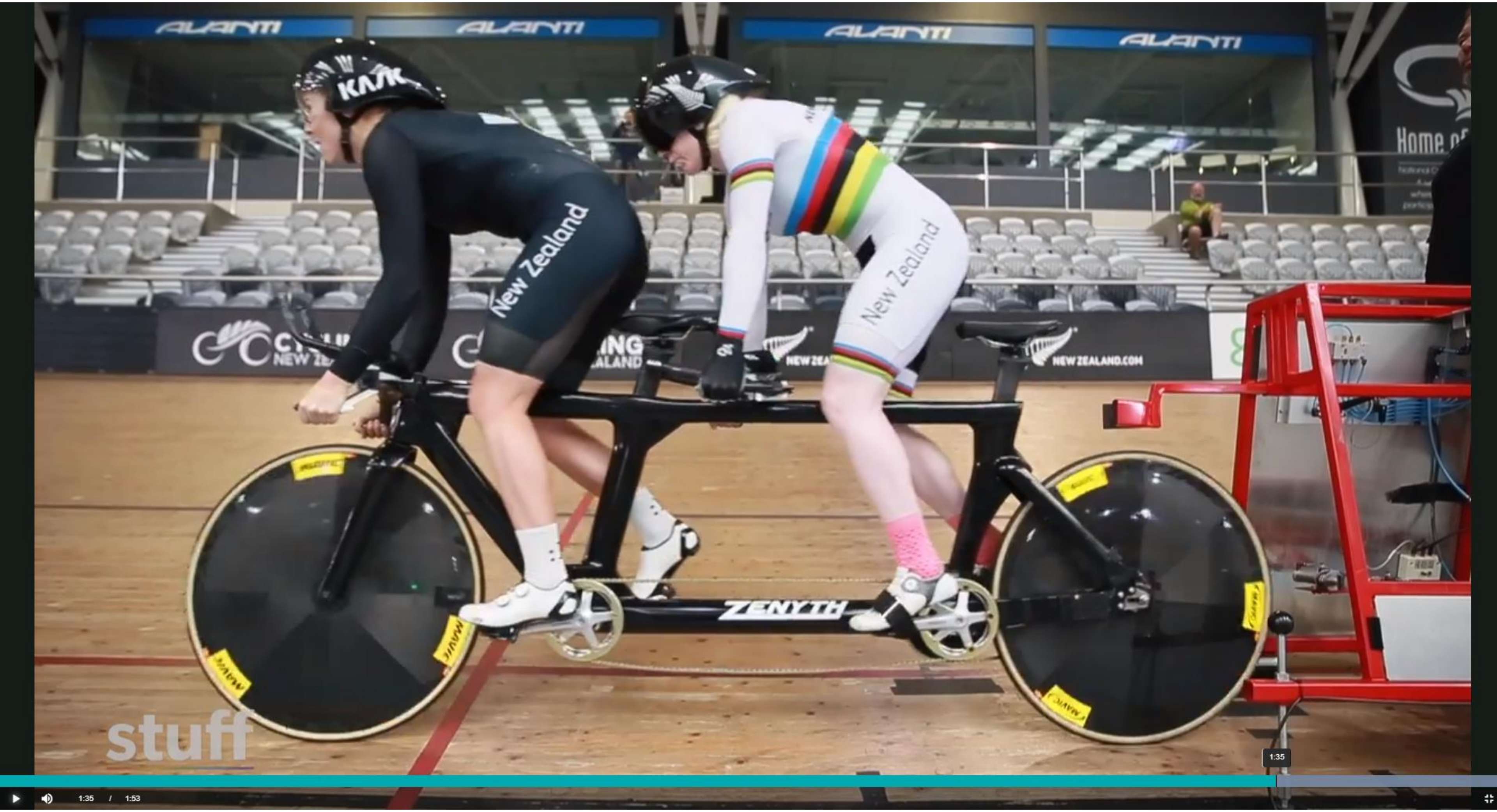

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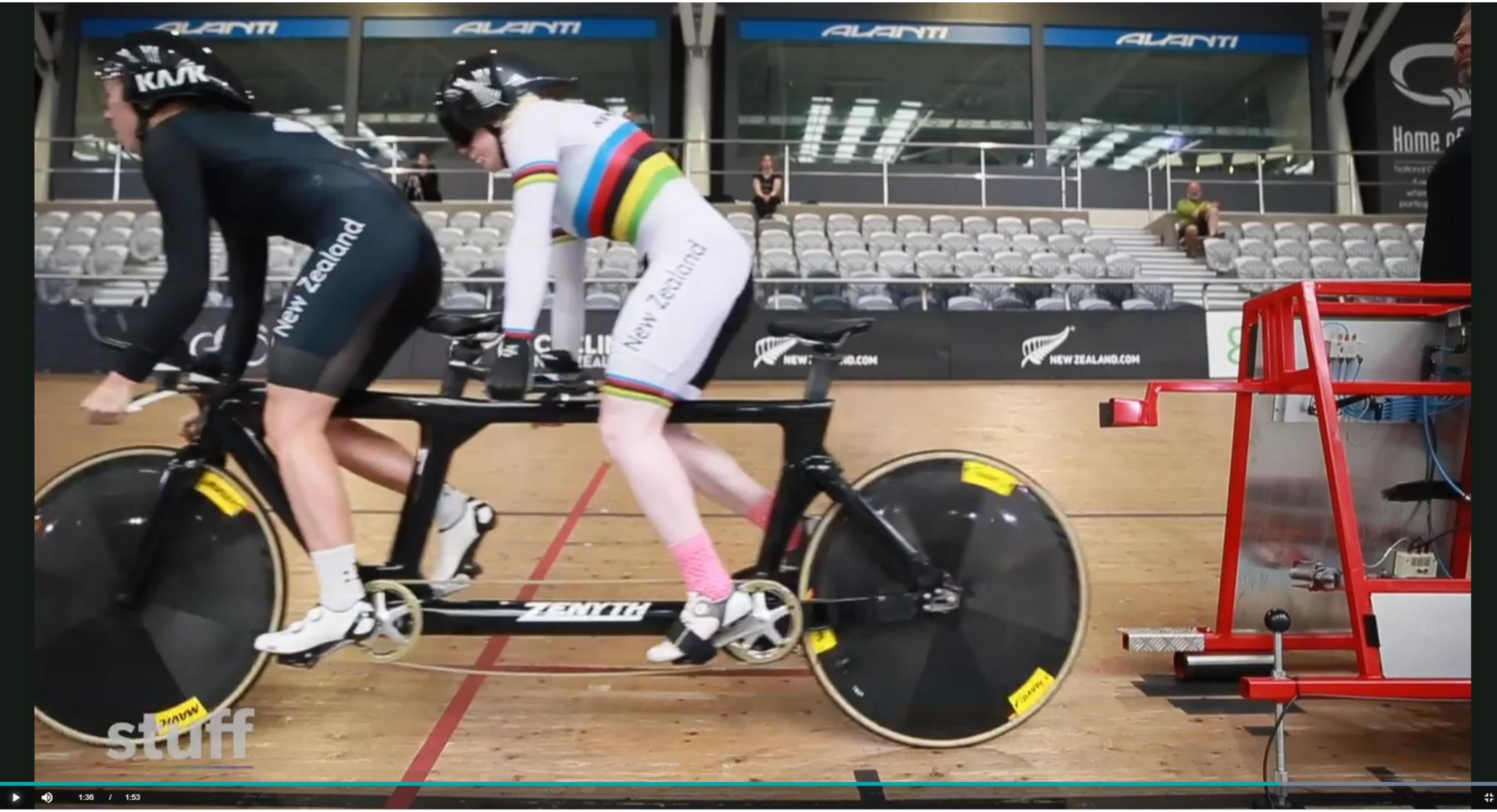

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Method: Calculation of forces

Approach

- Define bicycle geometry
- Define athlete mass and starting torque
- Consider equilibrium of:
  - Whole bicycle
  - Captain and stoker
  - Rear wheel
  - Both cranksets (pedal & chain forces)
- Output: forces acting on
  - Handlebars
  - Bottom brackets

Key assumption

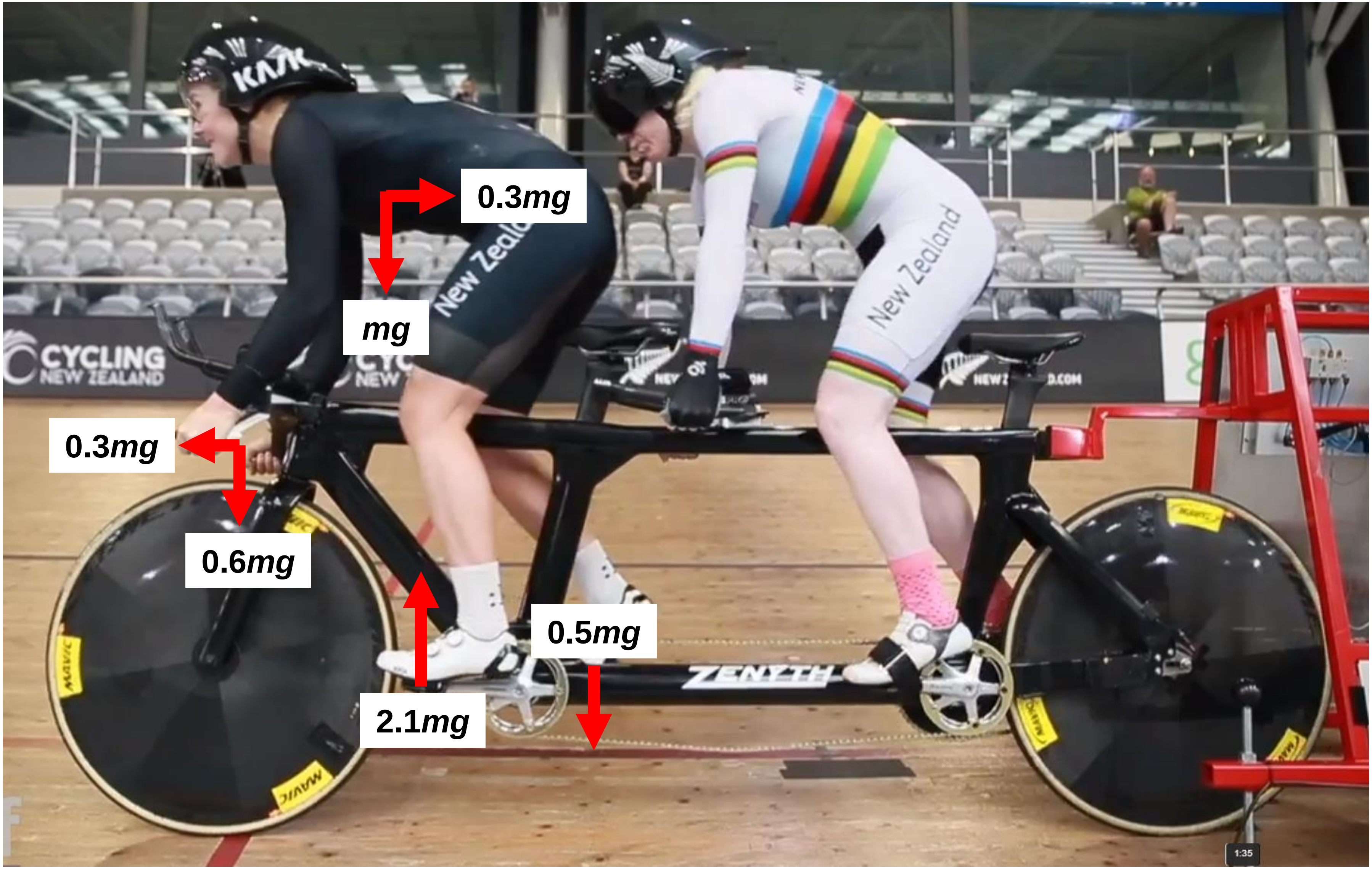
No horizontal forces on pedals [2]

Cyclists

Elite level females: 60 kg & 55 kg, 250 Nm each

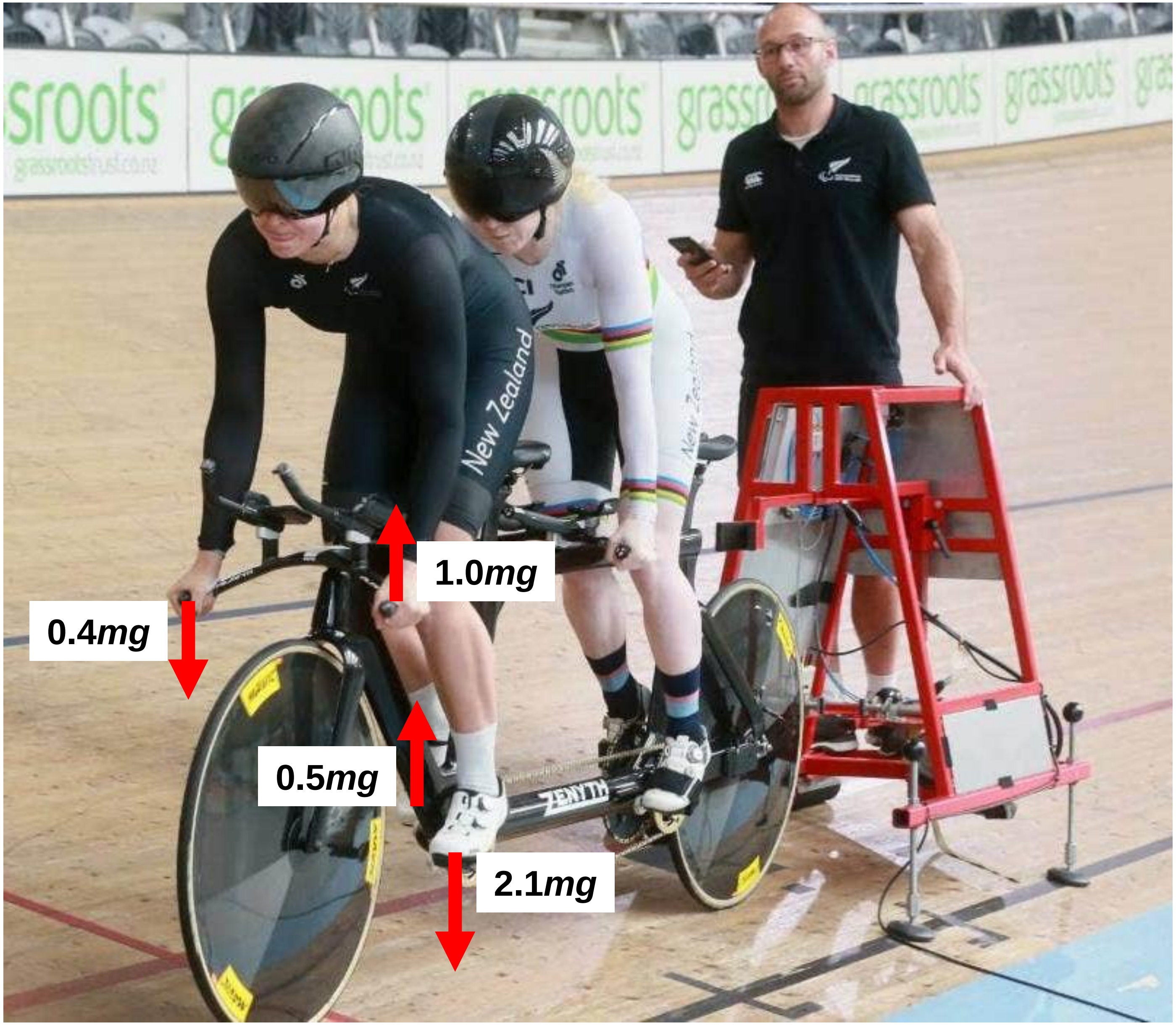
[2] Soden, P.D. and Adeyefa, B.A. (1979) Forces applied to a bicycle during normal cycling. *J. Biomechanics* 12:527-541

Method: Equilibrium of cyclist (estimated c.o.g. [3])

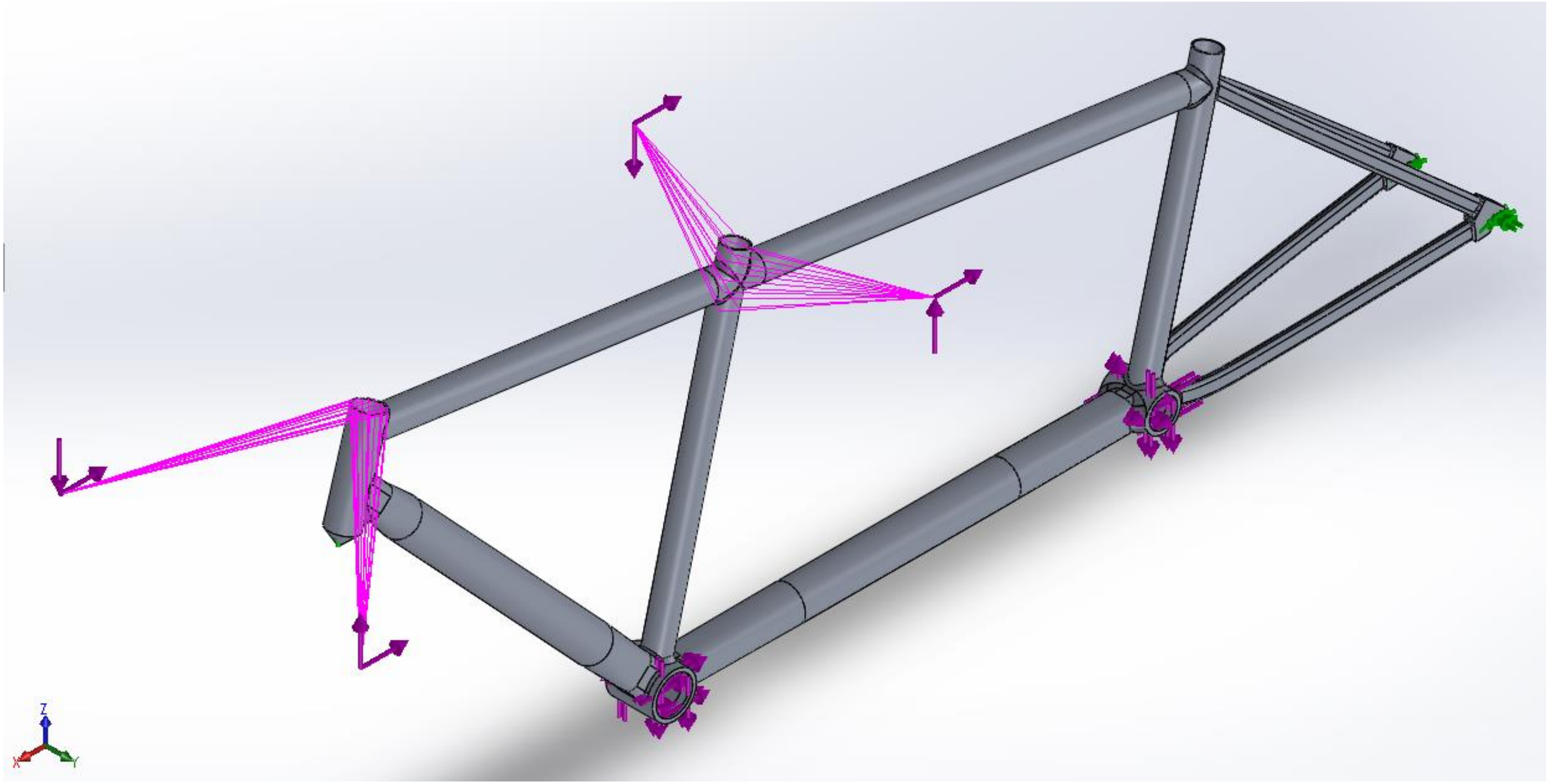


[3] Clauser, C.E., McConville, J.T. and Young, J.W. (1969) Weight, volume, and center of mass of segments of the human body. *AMRL TR 69–70, Wright-Patterson Air Force Base, Ohio (NTIS No. AD-710 622)*

Method: Vertical forces applied to bicycle

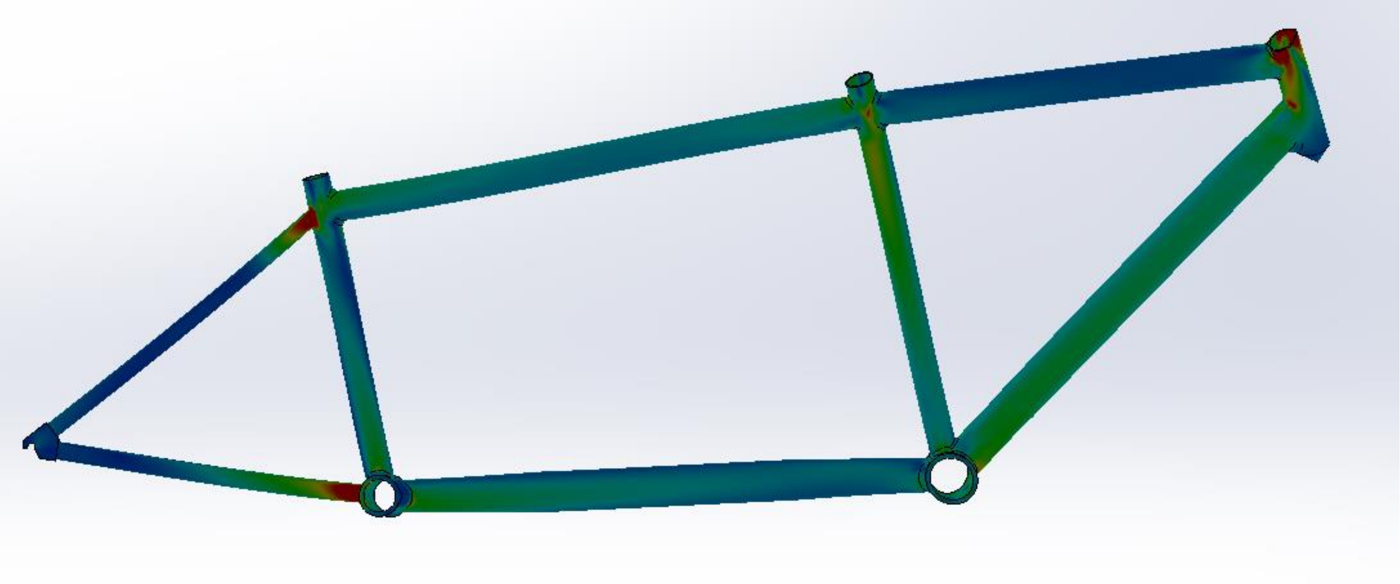


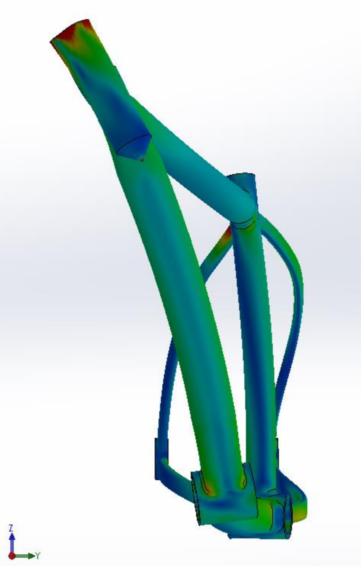
Method: Computational structural analysis

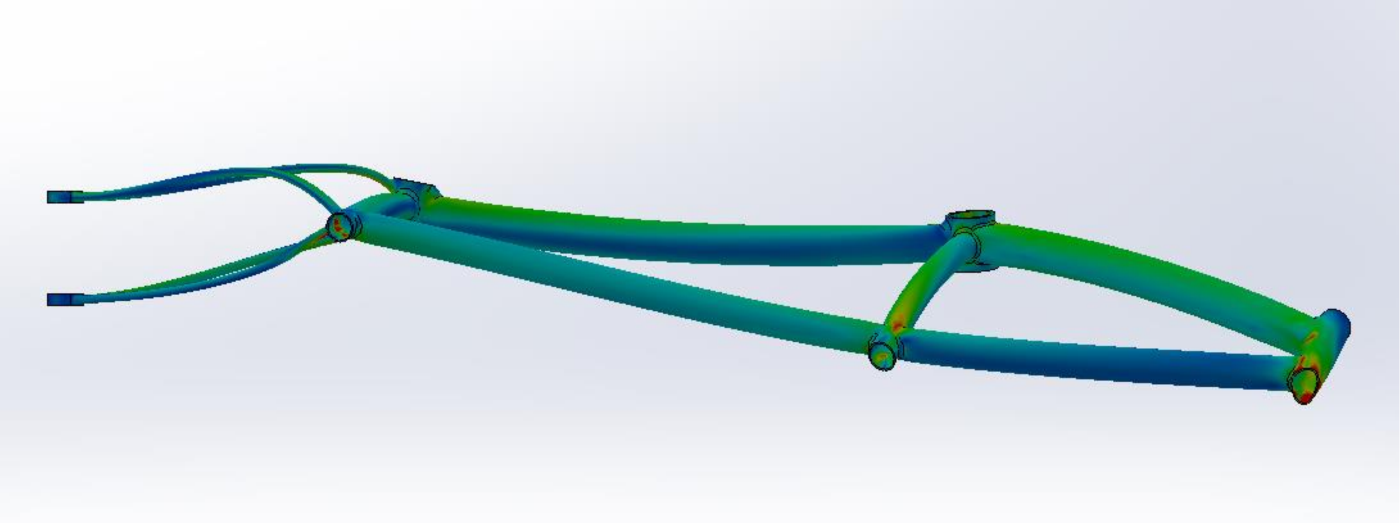


Results: Deflection

Open frame





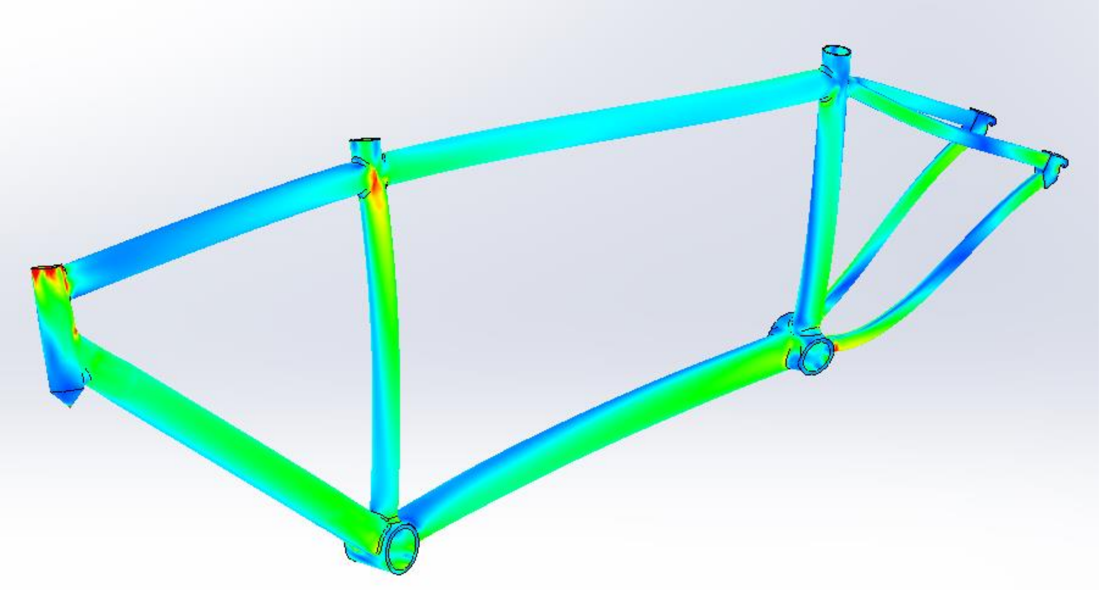


Results: Comparison of two frame types

Open frame

Aluminium tubing
- Diameters: 51 to 35 mm
- Wall thickness: 2 mm

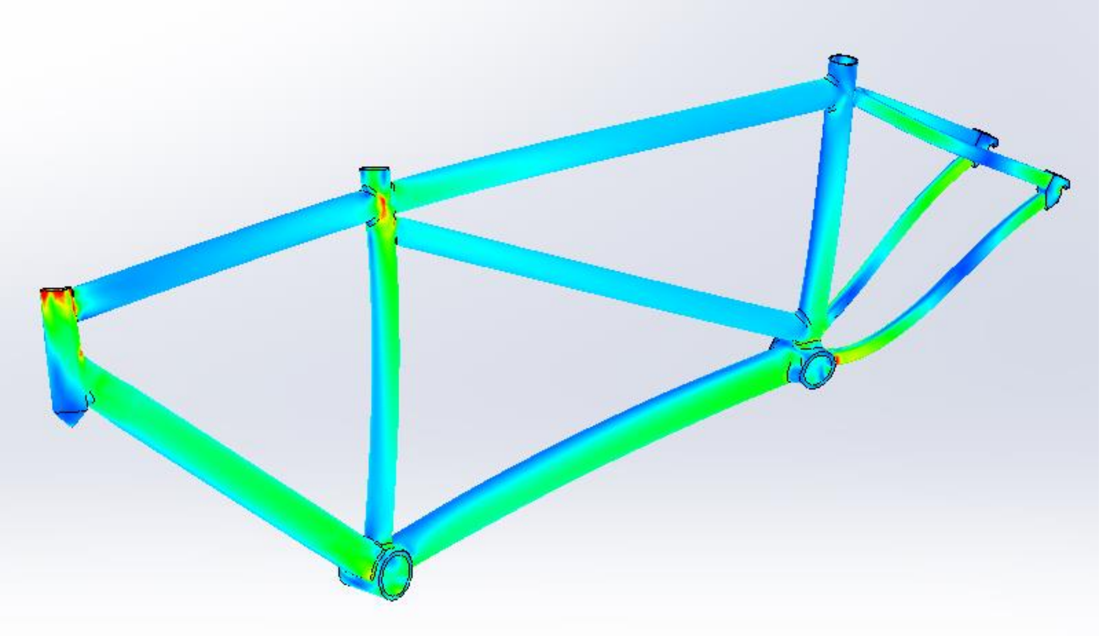
Frame mass: 3.29 kg



Double diamond

3.68 kg (12% heavier)

Vertical deflection
– 297% stiffer
Captain twist
– 8% stiffer
Stoker twist
– 25% stiffer



Conclusions & further work

Stiffness benefits

Additional bracing can provide torsional stiffness improvement. But …..

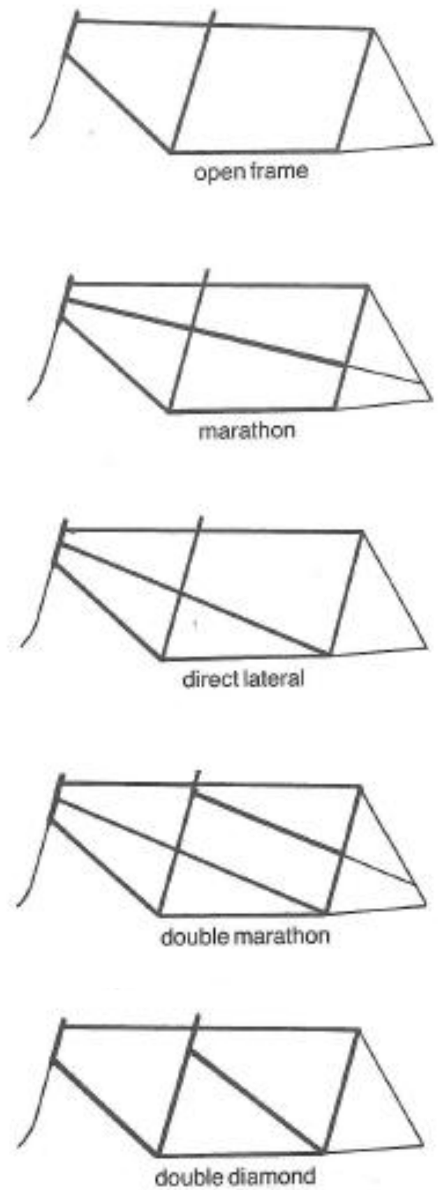
Effect on performance

Weight saving is worth ~ 0.1s/kg over a 3000m tandem pursuit race

Aerodynamic benefits of reduced bracing?

Next steps

Analyse marathon, double marathon and direct lateral designs

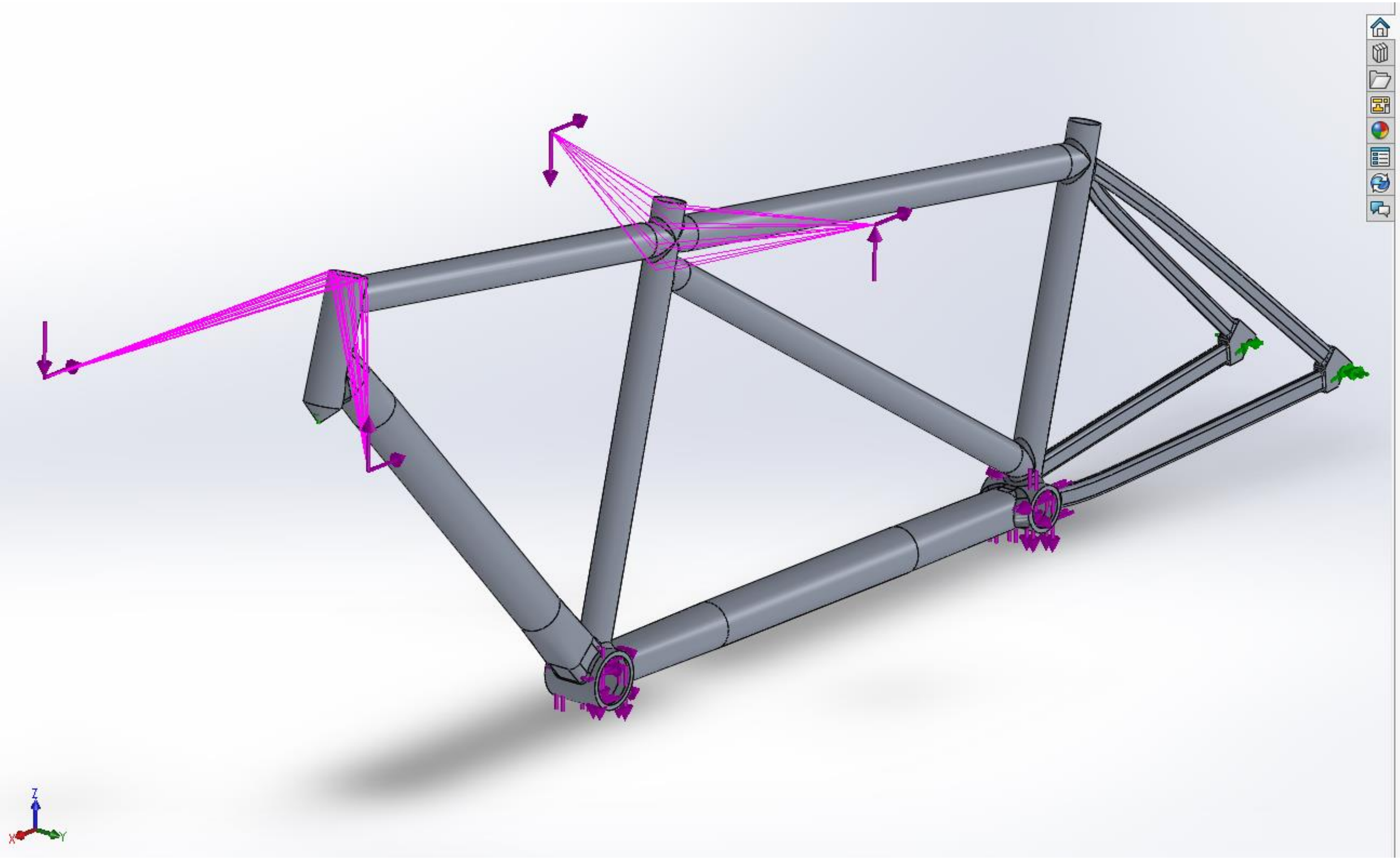


[4]

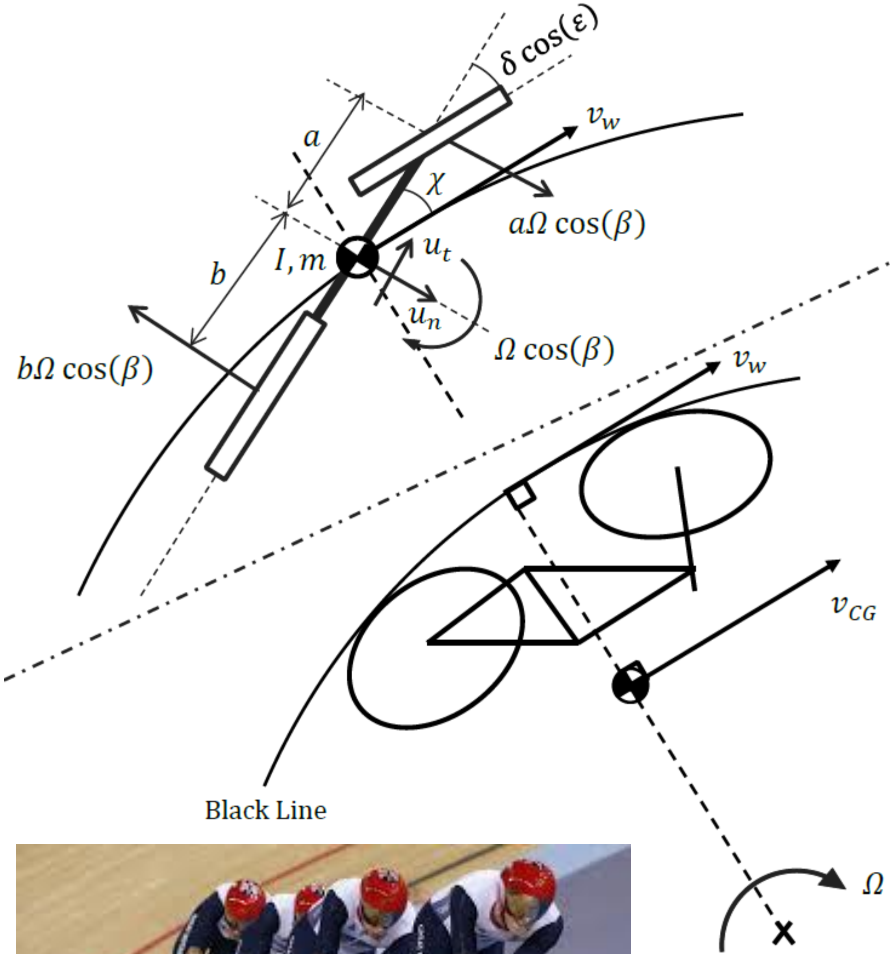
[4] Oliver, T. (1990) Touring bikes: A practical guide, The Crowood Press, UK.

Spare slides

Method: Computational structural analysis



Sports engineering: Design of optimal strategies for track racing



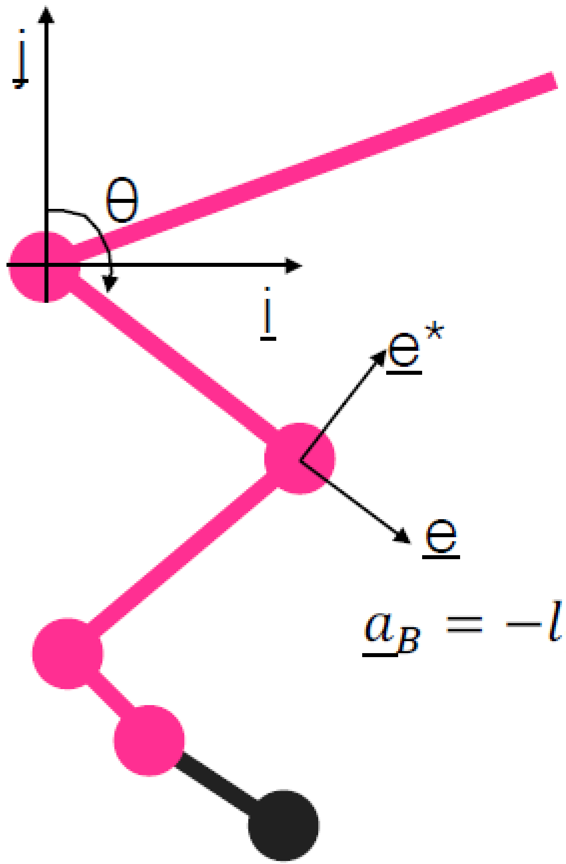
ENGLISH INSTITUTE OF SPORT

BRITISH CYCLING

Sports engineering: Biomechanics

Kinematic model

Velocity and acceleration of knee



$$\underline{v}_B = l_1\dot{\theta}\sin\theta\,\underline{i} + l_1\dot{\theta}\cos\theta\,\underline{j}$$

$$\underline{a}_B = -l_1\left(\ddot{\theta}\cos\theta + \dot{\theta}^2\sin\theta\right)\underline{i} + l_1\left(\ddot{\theta}\sin\theta - \dot{\theta}^2\cos\theta\right)\underline{j}$$